US009303486B2

(12) **United States Patent**
Getzlaf et al.

(10) **Patent No.: US 9,303,486 B2**
(45) **Date of Patent: Apr. 5, 2016**

(54) **TOOL ASSEMBLY INCLUDING AN EQUALIZATION VALVE**

(71) Applicant: **NCS Oilfield Services Canada Inc.**, Calgary (CA)

(72) Inventors: **Donald Getzlaf**, Calgary (CA); **Marty Stromquist**, Calgary (CA)

(73) Assignee: **NCS Multistage, LLC**, Calgary, Alberta (CA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 471 days.

(21) Appl. No.: **13/689,143**

(22) Filed: **Nov. 29, 2012**

(65) **Prior Publication Data**

US 2013/0133891 A1 May 30, 2013

Related U.S. Application Data

(60) Provisional application No. 61/564,657, filed on Nov. 29, 2011.

(51) **Int. Cl.**

E21B 34/12	(2006.01)
E21B 33/12	(2006.01)
E21B 43/26	(2006.01)
E21B 33/129	(2006.01)
E21B 23/00	(2006.01)
E21B 34/00	(2006.01)

(52) **U.S. Cl.**

CPC ***E21B 34/12*** (2013.01); ***E21B 23/006*** (2013.01); ***E21B 33/12*** (2013.01); ***E21B 33/1294*** (2013.01); ***E21B 43/26*** (2013.01); *E21B 2034/007* (2013.01)

(58) **Field of Classification Search**

CPC E21B 33/1294; E21B 2034/007; E21B 34/14; E21B 34/12

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,032,111	A	5/1962	Corley, Jr. et al.
3,273,649	A	9/1966	Moody et al.
3,845,818	A	11/1974	Deaton
4,421,182	A	12/1983	Moody et al.
4,804,042	A	2/1989	Knight et al.
5,842,521	A	12/1998	Tetzlaff et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CA	1298779	C	4/1992
CA	2693676	A1	7/2010

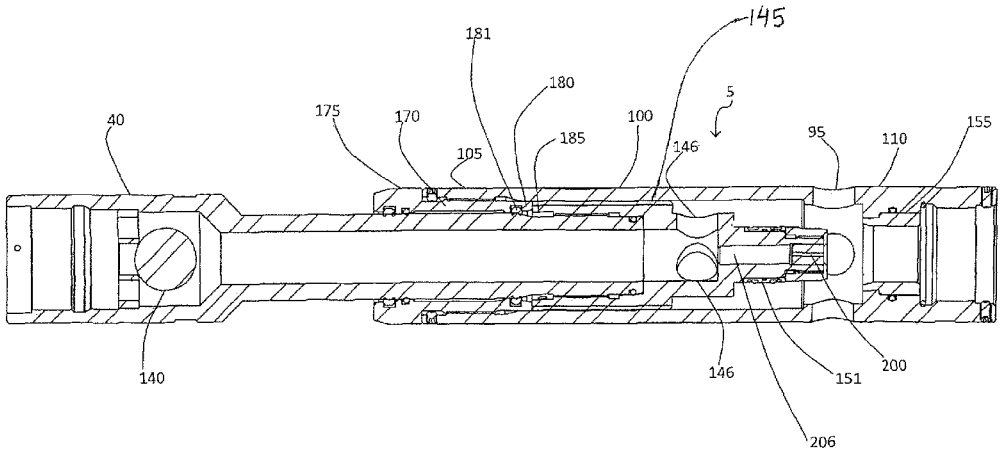
(Continued)

Primary Examiner — Jennifer H Gay
Assistant Examiner — George Gray
(74) *Attorney, Agent, or Firm* — Blank Rome, LLP

(57) **ABSTRACT**

A tool assembly including an equalization valve allowing for continuous equalization of pressure above and below a sealing element includes a housing having a fluid passageway that is fluidically continuous across a sealing element disposed on a mandrel. The mandrel is part of a sealing assembly that contains the sealing element. The equalization valve includes a valve plug moveable from an open to a seated position wherein the valve plug is seated against the sealing mandrel. The valve plug defines a conduit that provides minimal fluid flow across the sealing element when the valve plug is seated against the sealing mandrel. The equalization valve further includes an outer port for permitting lateral flow of fluid from the tubing string to the annulus defined between the tubing string and the wellbore. The equalization valve may be part of a downhole tool assembly which includes the equalization valve and a sealing assembly.

24 Claims, 8 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,289,990	B1	9/2001	Dillon et al.	
6,427,773	B1	8/2002	Albers	
6,474,419	B2	11/2002	Maier et al.	
6,655,461	B2 *	12/2003	Eslinger et al.	166/305.1
6,763,892	B2	7/2004	Kaszuba	
6,840,323	B2	1/2005	Fenton et al.	
7,913,770	B2	3/2011	Schramm et al.	
8,066,074	B2	11/2011	Maskos et al.	
D657,807	S	4/2012	Frazier	
2002/0062962	A1 *	5/2002	Gary et al.	166/305.1
2011/0198082	A1	8/2011	Stromquist et al.	
2012/0055671	A1	3/2012	Stromquist et al.	
2012/0090847	A1	4/2012	Getzlaf et al.	

FOREIGN PATENT DOCUMENTS

CA	2749636	A1	7/2010
CA	2738907	A1	7/2011
CA	2766026	A1	7/2011
EP	2105577	A1	9/2009
WO	WO-2012027831	A1	3/2012
WO	WO-2012051705	A1	4/2012

* cited by examiner

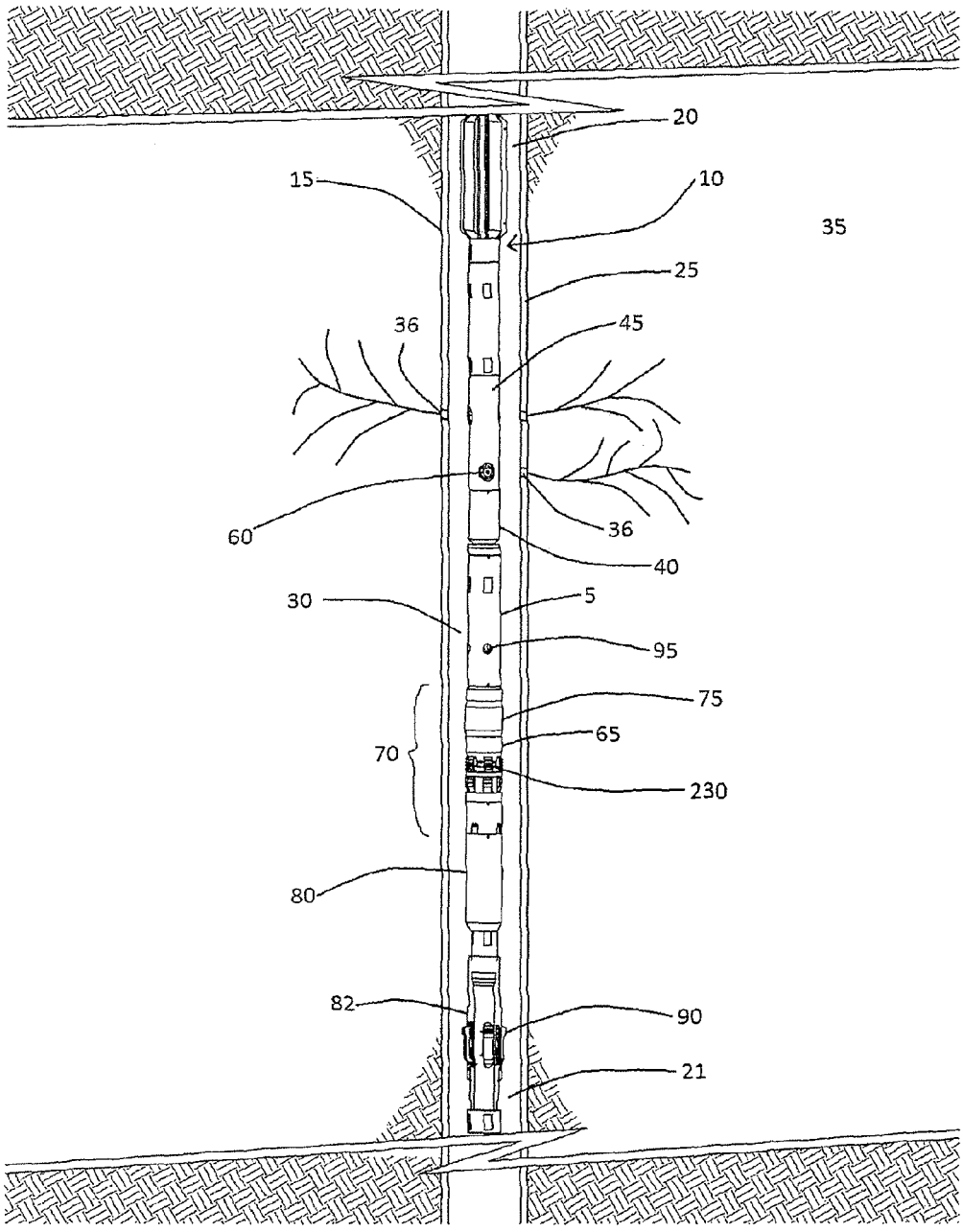


Figure 1

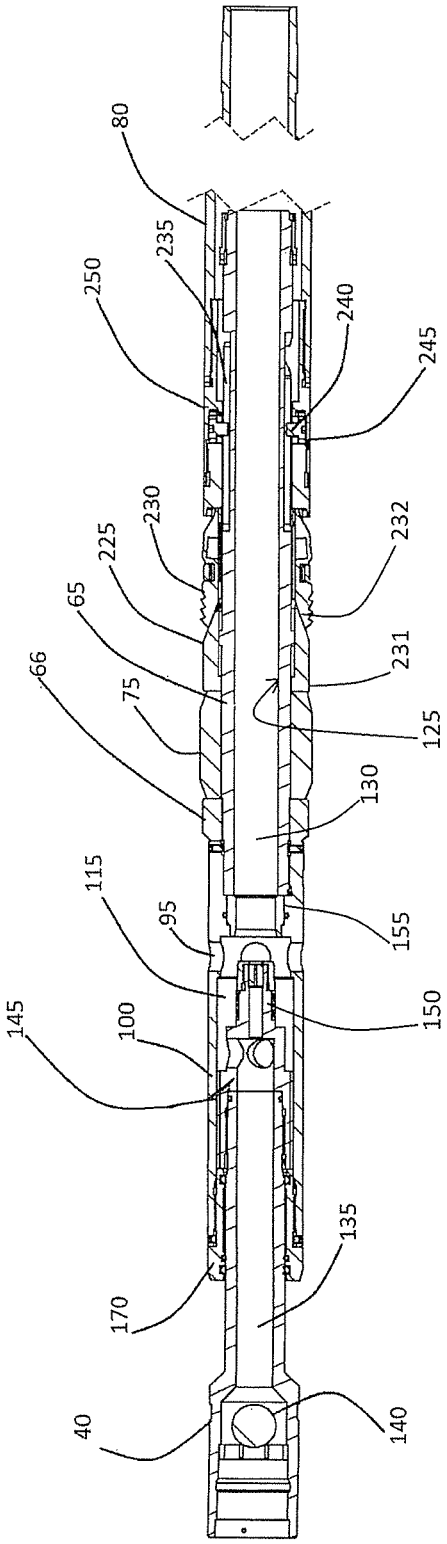

80
235
250
240
245
230
225
232
65
231
66
75
125
130
115
95
155
145
100
150
135
170
40
140

Figure 2

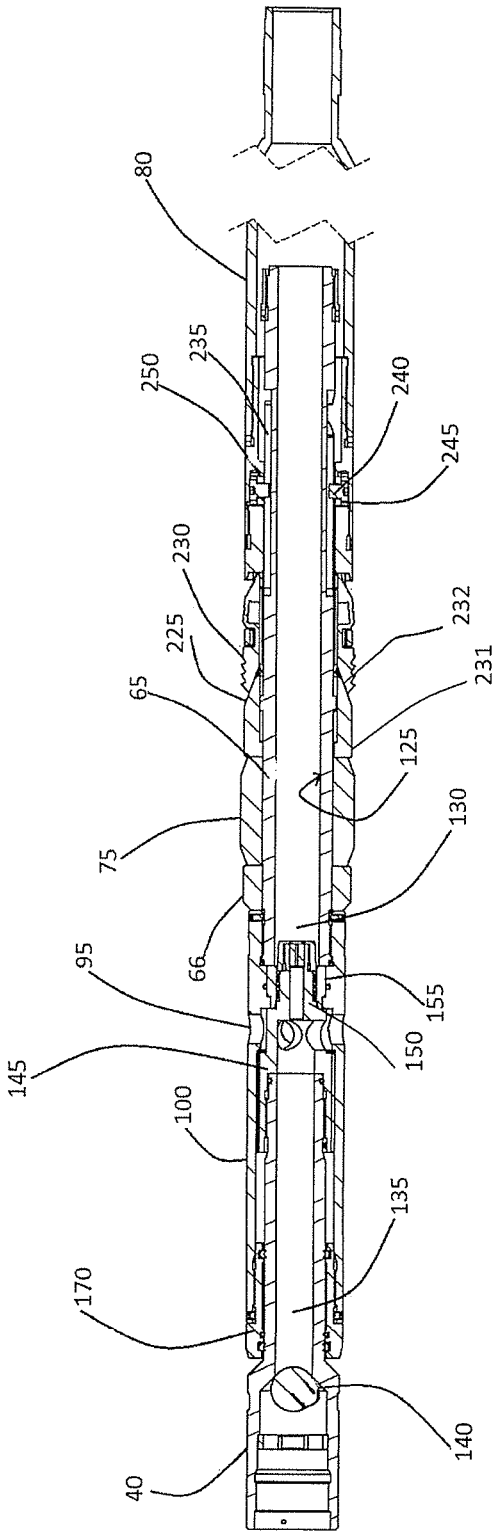

80
235
250
240
245
230
225
232
231
65
125
130
75
66
95
155
150
145
100
135
170
140
40

Figure 3

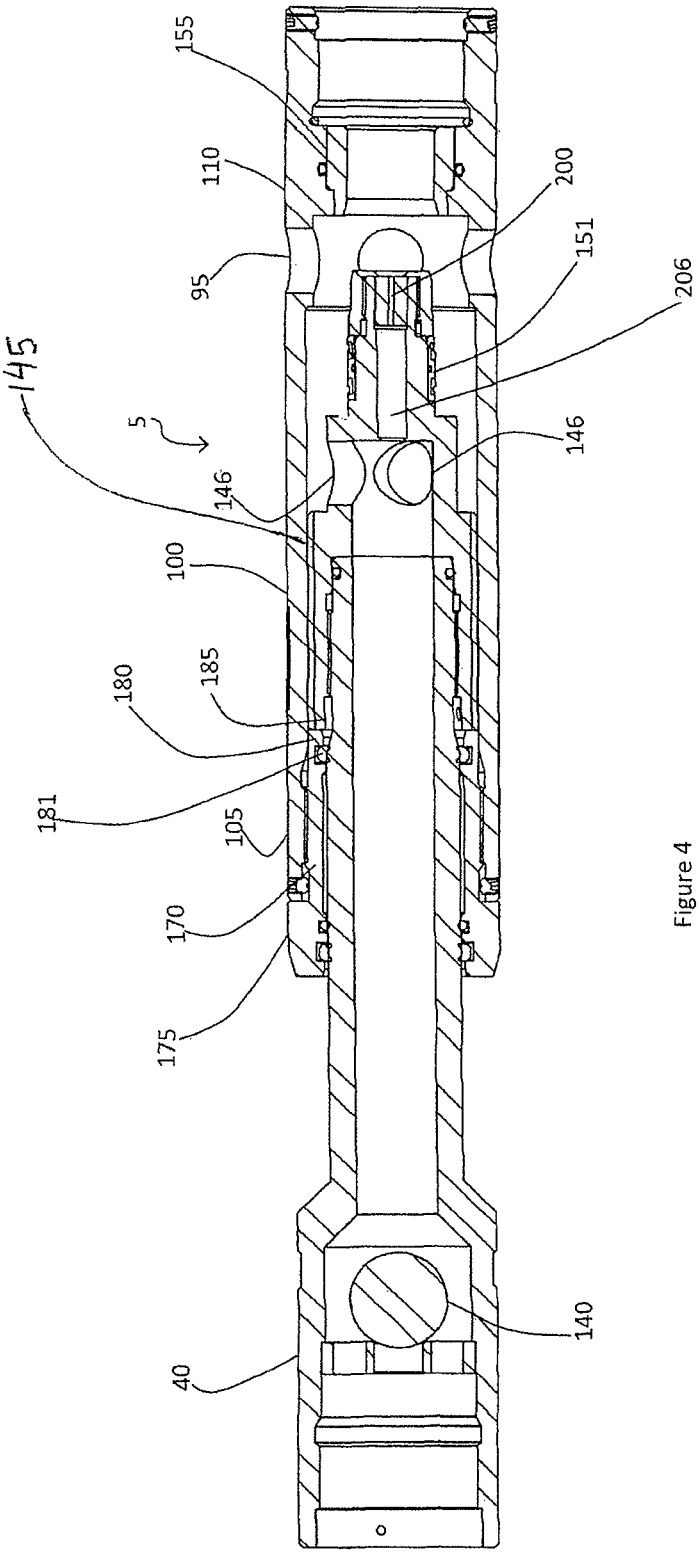

155
110
95
145
5
146
100
180
185
181
105
170
175
40
200
151
206
146
140

Figure 4

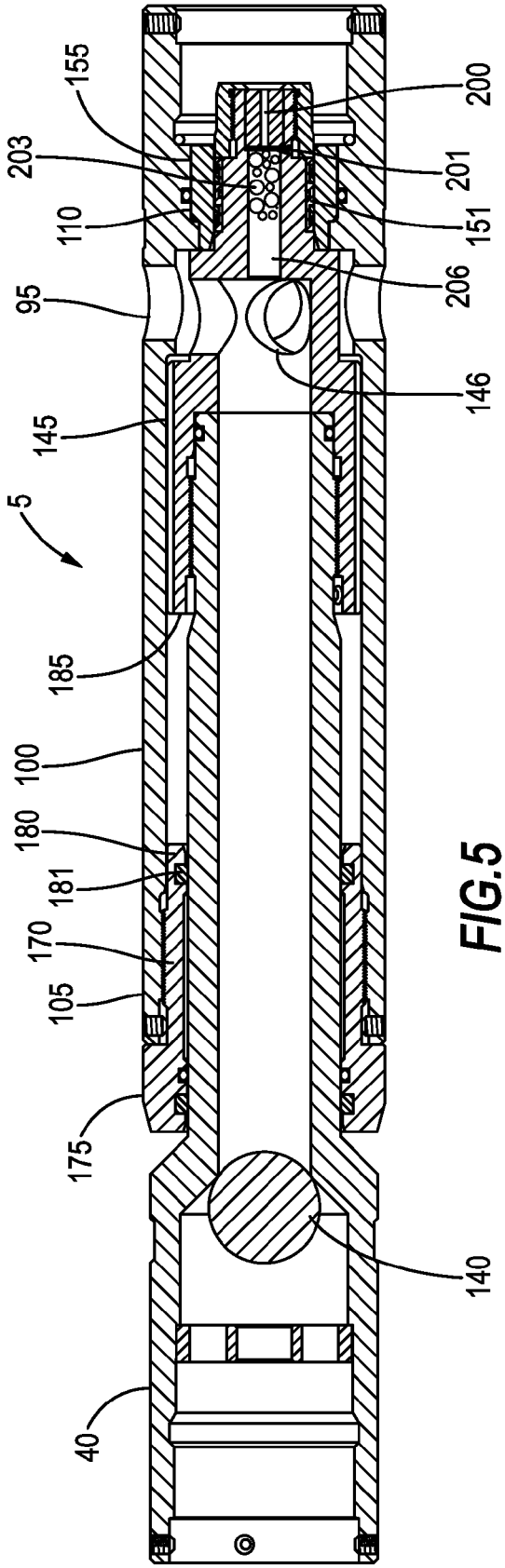

155
200
203
201
110
151
206
95
146
145
5
185
100
180
181
170
105
175
140
40

FIG.5

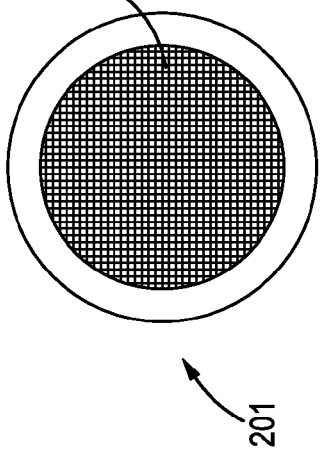

205
201

FIG.5A

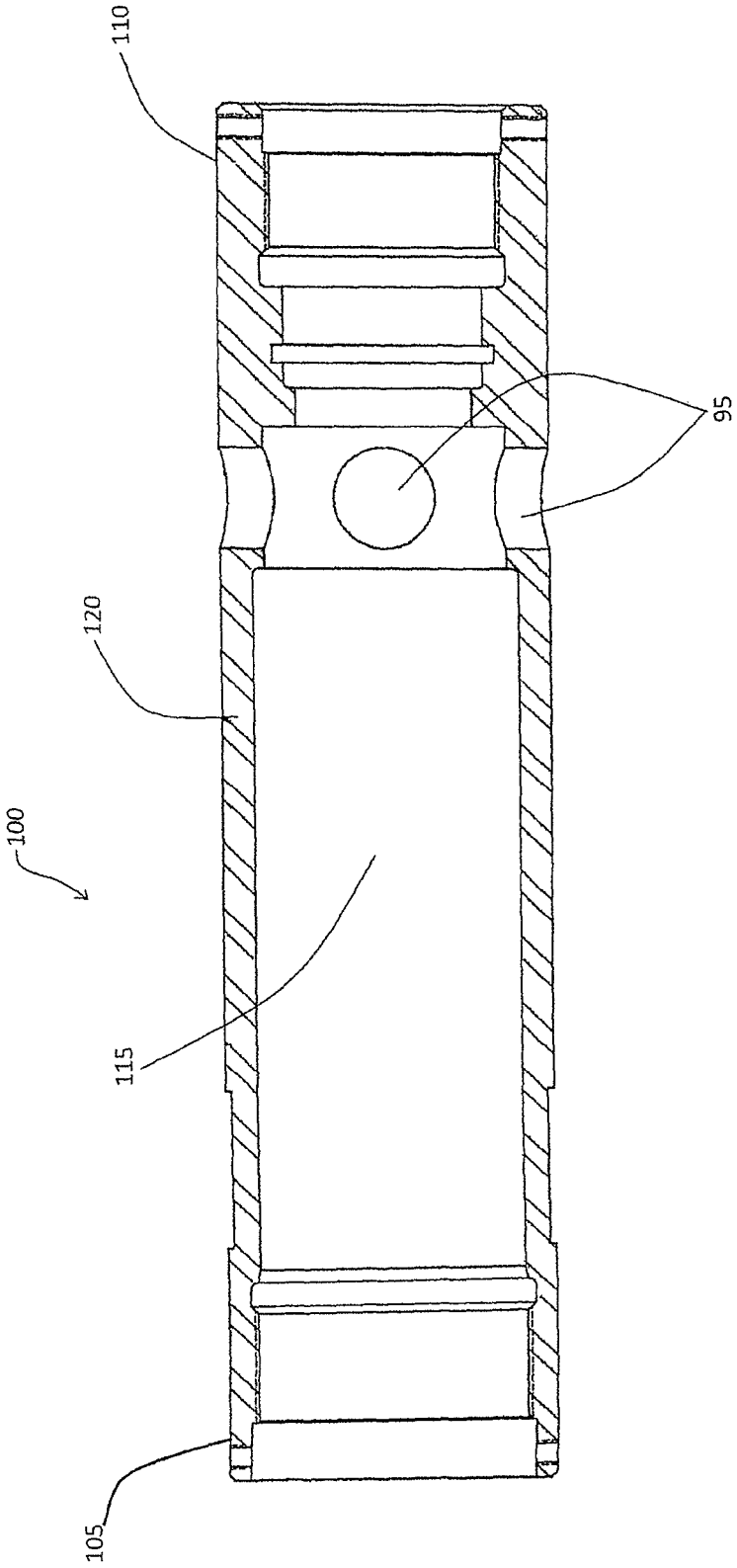


Figure 6

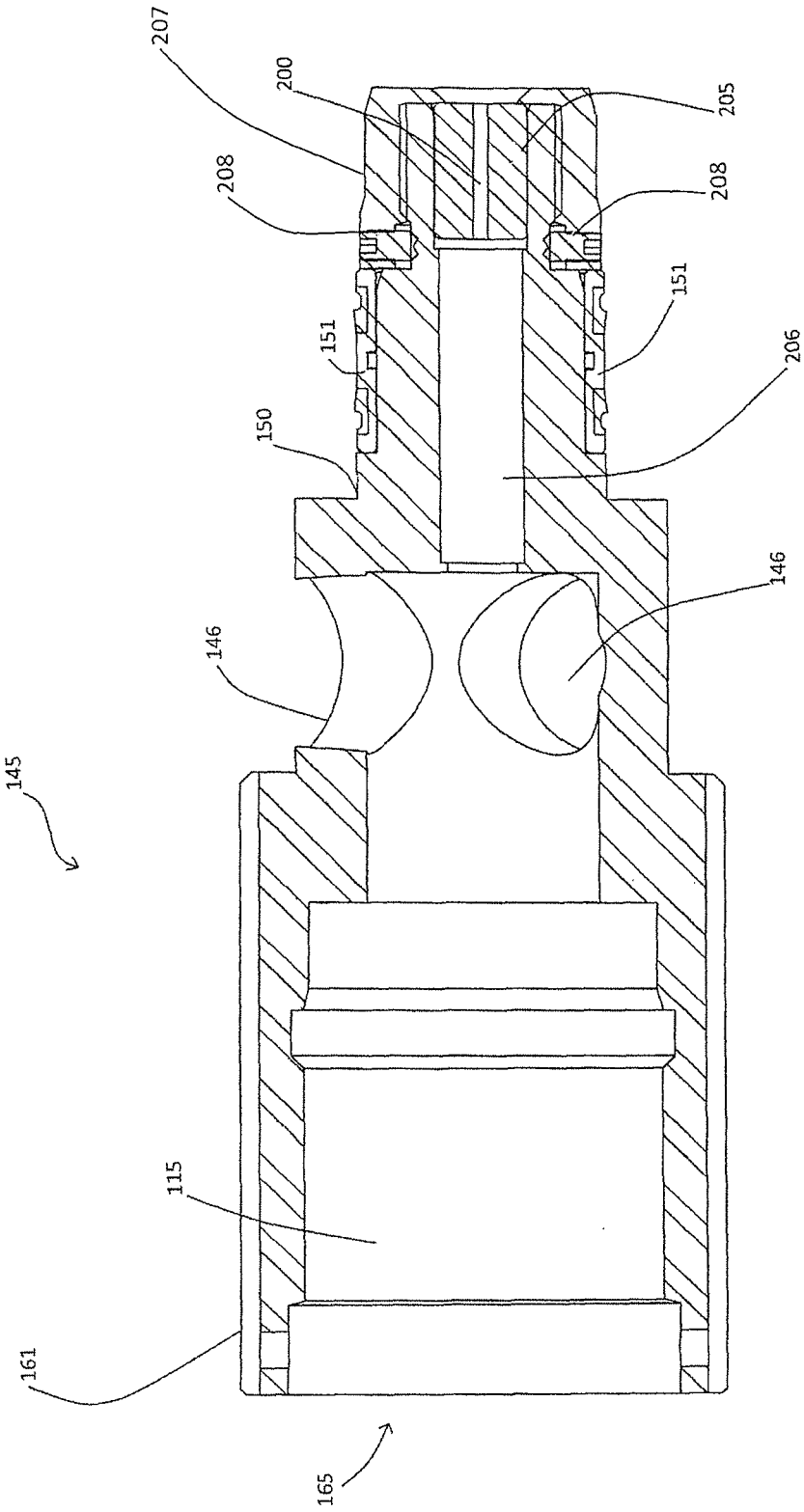


Figure 7

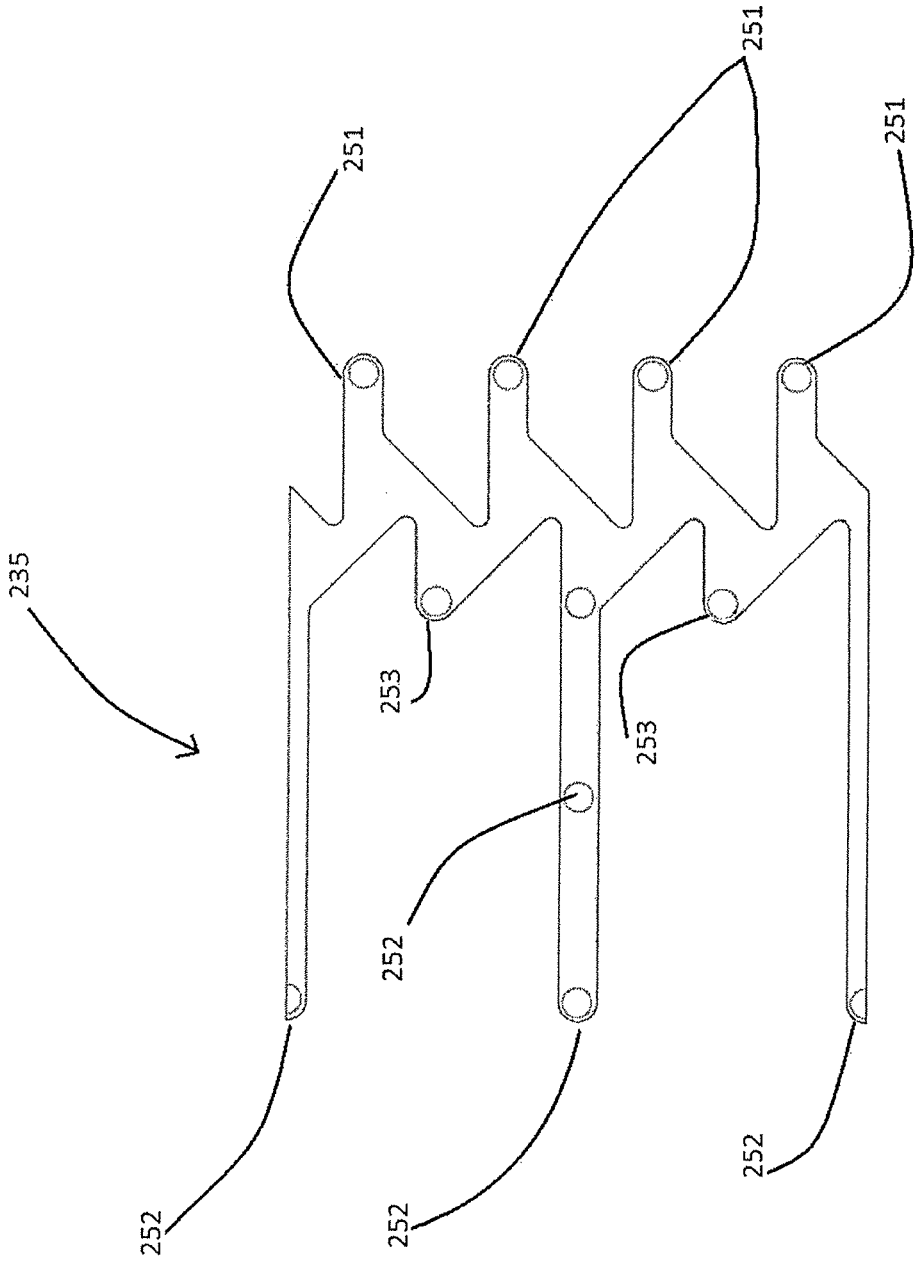


Figure 8

TOOL ASSEMBLY INCLUDING AN EQUALIZATION VALVE

RELATED APPLICATION

This U.S. patent application claims priority to U.S. Provisional Application 61/564,657 filed on Nov. 29, 2011, the disclosure of which is considered part of the disclosure of this application and is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

This relates to an equalization valve for use in a downhole tool assembly, and to the use of the tool assembly in fracturing operations.

BACKGROUND

Standard tools and methods for use in the completion of a wellbore are well known. Generally, perforations or ports are provided within cased wellbores for delivery of fluid treatment to the surrounding formation. Often, the completion of a wellbore requires fracturing of the formation by forcing proppant-laden fluid through the ports or perforations at high pressures. To efficiently isolate delivery of the fluid treatment to a particular wellbore region, sealing devices such as bridge plugs, friction cups, inflatable packers, and straddle packers are commonly used to isolate portions of the wellbore during fluid treatment. These devices are exposed to varying conditions during use, and debris accumulation around the tool assembly is a concern. When a sealing device is exposed to high fluid pressure differentials along its length, for example during an isolated fracturing operation, equalization of the pressure differential may cause damage to the sealing device. For example, following a fracturing operation, hydraulic pressure equalization across the sealing device will usually result in an immediate surge of fluid from the stimulated perforations or ports. This equalization surge in fluid flow will carry significant amounts of formation debris and sand such that, debris is likely to settle over and about the sealing device, or within other portions of the tool assembly. This may result in tool damage, or in the tool assembly becoming lodged within the wellbore. Increased pressure differential, sudden equalization, and any delay in removal of the tool assembly from the equalized segment further increases the risk of tool damage or lodgment downhole.

Accordingly, equalization across the sealing device during fracturing of sand-laden formations poses significant risk of debris-related tool malfunction, jamming or immobility of the tool assembly, and potential loss of the well if the tool assembly cannot be retrieved.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. **1** is a schematic perspective view of a tubing string with an equalization valve according to one embodiment.

FIG. **2** is a sectional view through the equalization valve and associated sealing assembly when the valve plug is in the open position according to one embodiment.

FIG. **3** is sectional view of the equalization valve and associated sealing assembly when the valve plug is in the seated position according to one embodiment.

FIG. **4** is a sectional view of the valve plug in open position with associated pull tube according to one embodiment.

FIG. **5** is a sectional view of the valve plug in seated position with associated pull tube according to one embodiment.

FIG. **5**A is a plan view of one embodiment of a filter element that may form a part of the valve plug shown in FIG. **5**.

FIG. **6** is a sectional view of the valve housing according to one embodiment.

FIG. **7** is a sectional view of the valve plug according to one embodiment.

FIG. **8** is a flat pattern on the J-slot defined in the sealing mandrel according to one embodiment.

SUMMARY

An equalization valve for continuous equalization of hydraulic pressure across a sealing element disposed on a tubing string is described. The valve, and a tool assembly which includes the valve, is adopted for insertion into a tubing string to assist in achieving selective equalization depending on the downhole operation being carried out. More particularly, the valve includes a moveable plug which allows for the selective flow of fluids across a sealing element.

According to one broad aspect, the equalization valve includes a housing having a primary fluid passageway which is continuous with a fluid passageway defined within a sealing mandrel. This primary fluid passageway may also be referred to herein as the primary equalization pathway. The sealing mandrel is part of a sealing assembly that includes a sealing element disposed around the sealing mandrel. The equalization valve also includes a plug that is moveable from a seated position in which it is engaged with the sealing mandrel to an open position in which the plug is unseated from the sealing mandrel. When the plug is in an open position, complete equalization of hydraulic pressure across the sealing element can be achieved because fluid can flow through the primary equalization passageway through the fluid passageway defined in the sealing mandrel and across the sealing element disposed thereon. The plug defines a conduit, the conduit being fluidically continuous with the fluid passageway of the sealing mandrel and the primary equalization passageway and allowing for a minimal fluid flow therethrough. The conduit forms a secondary equalization pathway that allows for fluid flow across the sealing element when the plug is in the seated position. The sealing element remains engaged against the wellbore while fluid flow through the secondary equalization pathway is occurring. Thus, this secondary equalization pathway allows for continuous equalization of hydraulic pressure across the sealing element without compromising the integrity of the sealing element against the wellbore.

In one embodiment, the equalization valve further includes at least one outer port that allows for fluid communication between the interior of the tubing string and the wellbore. The valve plug may also have at least one inner port. The inner port can be aligned with the outer port of the valve housing when the plug is in the seated position.

In one embodiment, the conduit, which forms the secondary equalization pathway in the valve plug may be provided as an insert, or as part of an insert which is positionable within a recess defined in the plug. The insert may be removed from the plug when continuous equalization across the sealing element is not desired.

According to one broad aspect, when performing downhole operations such as fracturing, the valve plug may be in seated position, with only a small amount of fluid flow through the secondary equalization pathway of the valve plug to the tubing string below the sealing element being permit-

ted. The sealing element remains set against the wellbore during this time. When operations are complete, the plug is moved from its seated position to an open or unseated position by application of a mechanical force to the tubing string. When the valve is in the open position, fluid flow through the primary fluid passageway of the equalization valve is permitted and hydraulic pressure across the sealing element is equalized as a result of the fluid flow. The sealing element returns to an unset set (where it is not compressed against the wellbore).

According to another broad aspect, the equalization valve may be part of an equalization assembly, the equalization assembly including both the equalization valve and the sealing assembly. The equalization assembly may be part of a downhole tool to be used in a debris-laden or high-solids environment. Permitting a relatively small amount of fluid communication across the sealing element so as to provide continuous equalization during fracturing reduces the excessive fluid and debris surge effect following termination of the fluid treatment, without compromising the isolation and without excessive fluid loss. Fluid passage across the sealing element may further serve to wash the tool assembly and wellbore below the sealing element.

In one broad aspect, there is provided an equalization valve adapted for insertion within a tubing string for deployment within a wellbore. The valve comprises:

- a valve housing comprising: a first end connectable to a length of tubing string and a second end connectable to a mandrel disposed on the tubing string, the housing further including a primary fluid passageway defined therethrough; the primary fluid passageway being continuous with a fluid passageway defined in the interior of the mandrel; and an outer port for permitting fluid flow from the interior of the tubing string to the wellbore;
- a valve plug slidably disposed within the equalization between a seated position and an open position, wherein in the seated position the valve plug is seated against the mandrel to an open position wherein valve plug is not seated against the mandrel; the valve plug including a conduit which is fluidically continuous with the fluid passageway of the mandrel and the length of tubing string above the housing, so as to allow continuous fluid flow across a sealing element disposed on the mandrel when the valve plug is in the seated position.

In one embodiment, the valve plug further includes an inner port that is fluidically continuous with the tubing string and can be aligned with the outer port of the valve housing when the valve plug is in the seated position.

In one embodiment, the primary fluid passageway of the valve housing may extend from the upper end of the valve housing to the lower end of the valve housing.

In one embodiment, the valve is associated with a sealing assembly which includes the mandrel and the sealing element, the valve plug being actuated from its seated to unseated position by a mechanical force applied to the tubing string.

In one embodiment, the upward movement of the valve plug is limited by engagement of a shoulder on the valve plug with of region of the tubing string at the upper end of the valve housing. The valve plug is coupled to a tubular element disposed on tubing string. The tubular element may be a pull tube. Mechanical force is applied to the pull tube to actuate movement of the valve plug.

In one embodiment, the valve plug may permanently connected, attached or affixed to the tubing string or it may be removable from the valve housing.

In one embodiment, the conduit in the valve plug may be provided as an insert, the insert being positionable within a recess defined in the valve plug. The insert is removable.

In another broad aspect, there is provided a tool assembly adapted for connection to a tubing string to be deployed within a cased wellbore. The tool assembly comprises:

- a sealing element disposed about a sealing mandrel on the tubing string, the sealing mandrel having a first end and second end, and defining a fluid passageway extending from the first end to the second end, the sealing element being actuable between a set position in which it is engaged against the casing to an unset position in which it is disengaged from the casing,
- an equalization valve comprising: a housing having a fluid passageway which is fluidically continuous with the fluid passageway of the sealing mandrel, an outer port for fluid communication between the interior of the tubing string and the annulus defined between the casing and the tubing string; and a valve plug slideable from a seated position in which the valve plug is in sealing engagement with the sealing mandrel to an open position in which the sealing mandrel is unobstructed by the valve plug, the valve plug further comprising a conduit of smaller size than the fluid passageway of the valve housing, to allow for fluid flow to the sealing mandrel when the plug is in the seated position, the sealing element remaining set against the casing while fluid flow through the conduit is occurring.

In one embodiment, the sealing element is actuated by a J-slot mechanism. The J-slot is formed within an outer diameter of the sealing mandrel.

In one broad aspect, there is provided a method of continuously equalizing pressure across a sealing assembly depleted in a cased wellbore. The method comprises:

- lowering a tubing string having a sealing assembly and equalization valve to a desired location in a wellbore, the tubing string being in fluid communication with the wellbore by a port defined in the equalization valve, the equalization valve having a primary fluid passageway defined therethrough for permitting fluid communication through the tubing string above and below the sealing assembly, and a secondary equalization passageway for allowing a restricted fluid flow above and below the sealing assembly;
- blocking fluid communication across the primary fluid passageway of the equalization valve, while permitting a restricted fluid flow to occur through the secondary equalization passageway;
- compressing a sealing element within the sealing assembly to engage and seal against the casing;
- performing downhole operation while the sealing element is set against the casing and the restricted fluid flow is occurring;
- applying mechanical force to the tubing string to allow fluid flow through the primary equalization passageway across the sealing assembly; and
- disengaging from the sealing element from the casing such that fluid flow can occur through the tubing string.

It is to be understood that other aspects of the teachings will become readily apparent to those skilled in the art from the following description, wherein various embodiments are shown and described by way of illustration.

DETAILED DESCRIPTION

This disclosure relates to an apparatus adopted for insertion into a tubing string. The apparatus may be an equalization

valve may be an equalization assembly which includes an associated sealing assembly, as will be described below.

The equalization valve is a dual-stage valve in that the valve provides for continuous equalization of hydraulic pressure across the sealing element at any time, as well as allowing for complete equalization of hydraulic pressure across the sealing element after wellbore operations are complete and it is desired to unset the sealing element from its engagement with the wellbore. The valve includes a narrow fluid conduit which provides a secondary equalization passageway allows for partial equalization of the pressure differential across the sealing element, preventing excess fluid surge and debris accumulation upon termination of fluid treatment and release of the sealing element. The secondary equalization pathway also provides for minimal washing effect, bathing the tool assembly below to prevent debris accumulation.

According to the present disclosure, a segment of the wellbore may be isolated, meaning that an effective hydraulic isolation is established in that the sealing element is in sealing engagement with the wellbore (which may be cased wellbore) and that no fluid can pass between the wellbore above the sealing element to the wellbore segment below the sealing element. A small amount of fluid flow is occurring across the sealing element, but this fluid flow does not affect the sealing engagement of the sealing element with the wellbore.

Referring to FIG. **1**, a schematic representation of an equalization valve **5** adapted for insertion within a tubing string **10**, according to one embodiment is shown. The tubing string **10** extends through a wellbore **15**. The tubing string **10** has an upper end **20** and a lower end **21**. A casing **25** may be disposed in the wellbore **15**. An annulus **30** is defined between the tubing string **10** and the casing **25**. The wellbore **15** intersects a formation **35**. The formation **35** is in fluid communication with the annulus **30** through perforations **36** within the casing **25**.

The equalization valve **5** is coupled at its upper end to a pull tube **40**. Pull tube **40** couples the equalization valve to a perforation sub **45**. The perforation sub **45** may include a perforation device **50** disposed thereon. The perforation device **50** may include one or more jet nozzles **60**.

The equalization valve **5** is connected at its lower end to sealing mandrel **65**. Sealing mandrel **65** is part of a sealing assembly **70**. Sealing assembly **70** also includes a resettable sealing element **75**. Mechanically actuated locking devices or slips **230** may be positioned below the sealing element **75** to resist movement down the wellbore when the sealing element **75** is in "set" position (i.e. sealed against the wellbore). As will be discussed below, the slips **230** may be actuated through a continuous J-mechanism. The lower end of sealing mandrel **65** is engageable with a crossover sub **80**. Crossover sub **80** may be coupled to an anchor sub **82**. Anchor sub **82** may include a mechanical casing collar locator **90**, or similar positioning device for locating sealing element **75** in the desired region of wellbore **15**.

The equalization valve **5** defines at least one outer port **95** which intersects a fluid passageway in the valve (the fluid passageway, as will be described below, is referred to as the primary equalization passageway). Thus, outer port **95** serves to communicate fluid flow between the annulus **30** and the interior of tubing string **10**. In addition, fluid communication between the tubing string **10** and the wellbore **15** can occur through perforations **36** in the casing **25**.

Referring to FIGS. **2** to **8**, equalization valve **5** comprises a valve housing **100** having an upper end **105** and a lower end **110**. Valve housing **100** defines a fluid passageway **115**, extending from the upper end **105** of valve housing **100** to the lower end **110** of valve housing **100**. The fluid passageway **115** of the valve housing **100** forms the primary equalization passageway of the tubing string into which the valve is inserted. By "primary" equalization passageway, it is meant that when unobstructed, this passageway allows for complete or substantially complete equalization of hydraulic pressure between the region of the tubing string **10** above the sealing element **75** and the region of the tubing string **10** below the sealing element **75**.

Referring to FIG. **6**, valve housing **100** has an outer port **95** defined in the wall **120** of equalization valve housing **100**. The outer port **95** is continuous with the primary equalization passageway **115** of valve housing **100**, and allows for fluid communication between the interior of the tubing string **10** and the annulus **30** formed between the exterior of the tubing string **10** and the casing **25**.

Valve housing **100** is connected at its lower end **110**, to a sealing mandrel **65** disposed on the tubing string **10**. The connection means may be a threaded connection, or any similar coupling or connecting means. Sealing mandrel **65** has an inner diameter **125** that defines a fluid passageway **130** that is continuous with the primary equalization passageway **115**. Valve housing **100** is connected at its upper end **105** to the tubing string **10**. In the embodiment shown in the figures, the upper end **105** of valve housing **100** is coupled with a pull tube **40** disposed on the tubing string **10**. Mechanical force can be applied to pull tube **40** to actuate the primary and secondary equalization pathways and to actuate sealing assembly **70**, as will be discussed in more detail below.

The pull tube **40** has a fluid passageway **135** defined therein. The fluid passageway **135** of the pull tube **40** is fluidically continuous with the primary equalization passageway **115** and with the inner passageway **130** defined in the interior of sealing mandrel **65**. Thus, fluid can flow through the tubing string **10** through the pull tube **40**, through the valve housing **100** and through the inner passageway **130** of sealing mandrel **65** to the tubing string **10** below sealing element **75**. The pull tube **40** may contain a ball and seat valve **140** to allow control of fluid backflow through from the equalization valve **5** to the tubing string **10** above the equalization valve **5**. Pull tube **40** is actuated by mechanical force applied to the coiled tubing to which it is connected.

A valve plug **145** is slidably disposed within valve housing **100**. The valve plug **145** includes a valve stem **150**. The valve stem **150** is sized for mating engagement within a valve seat **155** formed within sealing mandrel **65** so as to seal the inner passageway **130** of the sealing mandrel **65**. When valve plug **145** is in the seated position, fluid flow from the primary equalization passageway **115** to the inner passageway **130** of the sealing mandrel **65** is blocked. When the valve plug **145** is seated within the valve seat **155**, this position is referred to the seated or sealed position of the valve plug **145**, and this position defines the lowermost limit of movement of valve plug **145**. When the valve plug **145** is not seated within the valve seat **155** (i.e. open or unseated position), fluid can flow through the primary equalization passageway **115** to the inner passageway **130** of the sealing mandrel **65**.

The valve plug **145** has an inner port **146** that allows for reverse circulation of fluid through the tubing string. The inner port **146** can be aligned with the outer port **95** of valve housing **100** when valve stem **145** is seated within valve seat **155**.

Given the abrasive environment in which the equalization valve **5** may be operated, the valve stem **150** is composed of an erosion-resistant material such as a carbide or ceramic, and a seal **151** may be present about the valve stem **150** to seal against the primary equalization passageway **115** of valve housing **100** when the valve stem **150** is seated within valve

seat **155**. Also, the valve plug **145** may be machined to any suitable configuration that will provide a valve stem **150** for seating engagement with the sealing mandrel **65** on which sealing element **75** is disposed, and which is actuable by application of a mechanical force applied to the tubing string. The valve seat may also be formed in a connecting sub, for example, and valve seat as used herein includes any means to receive the valve stem so that it is engaged with the sealing mandrel.

The valve plug **145** has an enlarged upper end **161** which forms a hollow core **165** capable of receiving pull tube **40**. A lock nut **170** having an upper end **175** and a lower end **180** is connected to the upper end **105** of valve housing **100**, such that the upper end **175** of lock nut **170** forms a shoulder over the upper end **105** of valve housing **100**. A set screw **181** couples lock nut **170** to valve housing **100**. The lower end **180** of lock nut **170** and extends beneath the equalization valve housing **100** to engage with a shoulder **185** of the valve plug **145**. In this way, the lower end **180** of the lock nut **170** is sandwiched between the interior surface of equalization valve housing **100** and the exterior surface of pull tube **40**. The lower end **180** of the lock nut **170** thus defines a stop position for upward movement of the valve plug **145**. Thus, the uppermost position of the valve plug **145** occurs when the shoulder **185** of the valve plug **145** is abutted against a lower end **180** of lock nut **170**. Other means of coupling the plug to the valve housing are possible, so long as the plug is engageable with the tubing string, and that force can be applied to the tubing string to actuate movement of the plug.

A conduit **200** is defined within valve stem **150**. The conduit **200** is continuous with the primary equalization passageway **115** and the inner passageway **130** defined in the sealing mandrel **65**. This conduit **200** is also referred to a secondary equalization passageway because it is allows for continuous equalization of hydraulic pressure between the region of the tubing string **10** above the sealing element **75** to the region of the tubing string **10** below the sealing element **75**, even when the valve plug **145** is in the seated position within valve seat **155**.

In the embodiment shown in the figures, conduit **200** is provided within a valve insert **205**. The valve insert **205** is receivable within a recess **206** defined within the equalization valve stem **150**. The secondary equalization passageway **200** has a reduced size compared to the primary equalization passageway **115** so as to allow for restricted or reduced fluid flow compared to the fluid flow that would occur through the primary equalization passageway **115** when the valve plug is unseated. The insert **205** is removable. In the embodiment shown in the figures, the valve stem has a recess **206** defined therein, and the insert **205** is provided at the end of the flow path. Other arrangements are possible, provided that a minimal fluid communication pathway is formed between the valve housing **100** and the sealing mandrel **65** when the valve plug is in the seated position. In the embodiment shown in the figures, insert **205** is held in place by a back-up ring **207** which is turn held in place by set screws **208**. In this arrangement, the back-up ring will become engaged within valve seat **155** when valve plug **145** is in seated position.

A screen or filter **201** may be positioned across the secondary equalization passageway **200** to prevent sand and other debris from passing to the inner passageway **130** of sealing mandrel **65**. The filer may be a layer of particulate matter **203** held over the port and/or may include a screen **205** of appropriate mesh size. However, it is not necessary that there is a screen or filter, particularly when the equalization valve is used in conjunction with a downhole tool that incorporates many debris relief passageways.

As will be explained in more detail below, the sealing element **75** remains sealed against the wellbore despite this restricted fluid flow through the secondary equalization passageway because the force required to unseat and seat the valve plug **145** is less than the force required to actuate the sealing element **75**. The hydraulic flow is maintained even during the application of fluid treatment to the wellbore. Due to the relatively low rate of fluid passage, the hydraulic pressure above the sealing element is greater than the hydraulic pressure below the sealing element during application of fluid treatment. Thus, the seal may be pressure tested even with the continuous partial equalization across the sealing element. Further, both the treatment application pressure and bottomhole pressure may be monitored during fluid treatment.

The insert **205** is a carbide insert of the type normally used as a nozzle in jet perforation assemblies. The valve stem **150** is shaped to receive a jet perforation nozzle, for example of the type typically known, the nozzle having an outside diameter of about ½ inch and an inner diameter (which forms the secondary equalization passageway) varying from about ⅛ inch to ⅜ inch. Such inserts are known in the field and are readily available. However, as stated, there is no requirement for the secondary equalization passageway to be provided as an insert within the valve stem, and the valve stem may simply have a permanent conduit provided therein, the conduit forming the secondary equalization passageway. For example, the insert may be selected from a set of modular inserts, each insert of the set having a conduit (which forms the secondary equalization passageway) of varying size. Therefore, the amount of fluid flow across the sealing element can be selected depending on the application in question.

A variety of sizes for the conduit **200** may be suitable, but typically the conduit **200** will have a diameter between ⅛ inch and ¾ inch. For example, a 3/16 inch diameter is deemed suitable. The configuration of the conduit may be customized to a particular wellbore, completion, or operation. When the conduit is provided as an insert within the valve stem, it may be replaced as needed with another suitable insert. In addition, the entire valve plug may be removed from the equalization and replaced as needed.

Referring to FIGS. **2** to **7**, the equalization valve **5** is associated with a sealing assembly **70**. The sealing assembly **70** includes sealing mandrel **65**, a gage ring **66**, a compressible sealing element **75** disposed about sealing mandrel **65** and setting cones **225** disposed about sealing mandrel **65**. In the set or sealed position, sealing element **75** is engaged against the casing **25** to seal fluid flow from the region of the wellbore above the sealing element **75** to region of the wellbore below the sealing element **75**. Setting cones **225** are disposed about the sealing mandrel **65**. Setting cone **225** has an upper end **231** and a lower tapered end **232**. Upper end **231** of setting cone **225** engages lower end of sealing element **75** while tapered end **232** of setting cone **225** extends radially outward from sealing mandrel **65**. Lower tapered end **232** is juxtaposed against mechanically actuated slips **230** which are also disposed around the sealing mandrel **65**. These slips **230** are adapted to engage the casing **25** when the sealing element **75** is set, as will be described below. The gage ring **66** is positioned about sealing mandrel **65** such that it engages the lower end of sealing element **75**.

A J-slot **235** is defined within the outer diameter of the sealing mandrel **65** for actuating the sealing element **70**. Various J-slots suitable for actuating mechanical set packers and other downhole tools are known within the art. The J-slot **235** illustrated in the FIG. **8** is a continuous J-slot. At least one J-pin **240** extends outwardly from sealing mandrel **65** and is retained within J-slot **235** defined in sealing mandrel **65**. The

J-pin **240** is held is place by a clutch ring **245**. The clutch ring **245** is comprised on two concentric halves, which together encompass the outer diameter of sealing mandrel **65**. The clutch ring **245** is held in place against sealing mandrel **65** in a clutch housing **250**. The clutch housing **250** is threadedly connected to crossover sub **80**. Thus, the clutch housing **250** couples the crossover sub **80** with sealing mandrel **65**. The crossover sub **80** may be coupled to an anchor sub that holds the mechanical collar locator or similar locating device. Alternative arrangements are possible.

Debris relief apertures may be present at various locations within the J-slot **235** to permit discharge of settled solids as the J-slot **235** slides relative to J-pin **240**. The J-slot **235** is also deeper than would generally be required based on the pin length alone, which further provides accommodation for debris accumulation and relief without inhibiting actuation of the sealing element. As shown in FIG. **8**, J-slot **235** has 3 pin positions: a set position **252** (in which the sealing element is engaged against the wellbore and the equalization valve seated), a pull position **251** (in which the sealing element is not engaged against the wellbore) and a run position **253** (in which the equalization valve is unseated and the equalization valve is not set).

Operation:

Generally, the equalization valve may be used in fracturing and in particular when fracturing in the presence of sand and other debris. When a downhole operation is to begin, a tubing string, such as that schematically shown in FIG. **1**, is lowered into the wellbore **15**. Once the sealing element **75** reaches the desired location within the wellbore **15**, an upward force is applied to the pull tube **40**. This causes the locator such as the mechanical collar casing locator to engage the casing. Upward pull is stopped and then, downward force is applied.

The downward force applied to the pull tube **40** causes the valve plug **145** to disengage from its abutment with the lock nut **170** and move downward to its seated position within the valve seat **155**. Continued downward force on the pull tube **40** causes the sealing mandrel **65** to slide downward relative to the J-pin **240** which is held in position by clutch ring **245**.

As this downward force is occurring, J-pin **240** will be moved from the pull position **251** to the set position **252**. As the sealing mandrel **65** slides downward, slips **230** are driven outward to engage casing due to the resistance of the setting cone **225** against slips **230**. Sealing element **75** is positioned between gage ring **66** and setting cone **225** and downward movement of sealing mandrel **75** causes the sealing element to push outward, sealing against the casing **25**. In the set position, fluid flow from the wellbore above the sealing element **75** to the wellbore below the sealing element **75** is prevented. In this position, equalization plug is in the seated position, and fluid flow through the primary equalization passageway **100** is prevented. However, fluid flow through the secondary equalization pathway **200** can still occur. The sealing element **75** remains set against the casing **25** while this restricted fluid flow is occurring. In addition, fluid communication between the tubing string **10** and the annulus **30** defined between the casing **25** and the exterior of the tubing string **10** is possible through the outer port **95** defined in valve housing **100** and the inner port **146** defined in valve plug **145**. During this time, operations such as fracturing can be performed. Sand-laden fluid is pumped into the formation, through the casing or annulus, or both.

Once operations are complete, the downhole tool assembly is to be moved to a new location, and thus, the sealing element **75** must be unset. Upward force is applied to the pull tube **40**, the valve stem **150** is disengaged from it seated position within valve seat **155** and slides upward, until the shoulder of the valve plug **145** is abutted against lock nut **170**. As the valve stem **150** is not seated within sealing mandrel **65**, fluid flow can occur between the tubing string above and below the sealing element **75** through the primary equalization pathway **115** defined in the valve housing **100**.

Fluid flow can also occur between the outer port **95** of the equalization valve **5** and the interior of the tubing string **10**, allowing for complete equalization of pressure within the lateral direction (i.e. between the interior of the tubing string and the annulus) and the longitudinal direction (i.e. within the tubing string). Because fluid can flow down the tubing, hydraulic pressure is equalized. As the lower end **110** of the valve housing **100** is attached to the sealing mandrel **65**, continued upward force applied to the pull tube **40** will also slide sealing mandrel **65** upward, and J-pin **240** will gradually be pulled upward, from a set position **252** to a pull position **251**. The sealing element **75** returns to its unengaged or decompressed state (where it is not set against the casing), the setting cone **225** is pulled upward by the sealing mandrel **65** and the slips **230**, no longer being pressed into the casing **25** by the setting cone **225** are forced back into a tuck position by springs. Thus, these actions will cause sealing element **75** to disengage from casing **25** and slips **230** to disengage from the casing **25**. The downhole tool assembly can then be moved to a different wellbore segment to be treated.

In respect of the differing forces required to seat and unseat the valve plug and to set and unset the sealing element, the following is noted: after the tool assembly is moved to the appropriate location and the locator (such as the mechanical collar locator) is engaged with the casing, a first mechanical force is applied to the tubing string (through the coiled tubing connected thereto) so as to seat the valve plug **145** in the valve seat **155**. A second mechanical force is then applied to move the sealing mandrel **65** relative to J-pin **240** so that the J-pin **240** is moved from the run position **253** to the set position **252**. The second mechanical force is generally greater than the first mechanical force. As fracturing operations are occurring, a hydraulic pressure differential is created across the sealing element **70**. Once operations are complete, the valve plug is moved to its unseated or open position by mechanical force applied to the tubing string **10**. As fluid flow can occur across the sealing element **70**, hydraulic pressure is quickly equalized. The sealing element **70** becomes disengaged and the sealing mandrel **65** can be slide relative to J-pin **240** such that J-pin **240** moves from the set position **252** to the pull position **251**.

In any of the embodiments described herein, many fluid communication pathways are available for debris relief, whether the sealing element is set or unset, and whether the valve plug is seated or unseated. In any position of the valve plug, fluid communication between the annulus and the valve housing is available, and when the ball and seat are not present above the pull tube, fluid may be circulated from the tubing string to the valve housing and wellbore annulus. Thus, two potential circulation flowpaths from surface to the treated interval are provided—through the tubing string or down the wellbore annulus. Using the presently described valve and suitable variants, fluid may be circulated through the valve housing when the equalization valve is in any position, providing constant flow through the secondary equalization pathway to prevent clogging with debris. Accordingly, the equalization valve may be particularly useful when incorporated into downhole assemblies deployed in sand-laden environments.

While the above-mentioned embodiments describe a sealing element, any suitable sealing device that permits effective hydraulic isolation of the interval to be treated may be used.

For example, inflatable packers, compressible packers, bridge plugs, friction cups, straddle packers and others known in the art may be used. Such sealing devices are generally used with a locating device to ensure that the seal is placed at the appropriate location of the wellbore segment. Also, the sealing assembly may have variations, and may not include the exact features of the sealing assembly described herein.

When a jet perforation assembly is present above the pull tube **40**, a ball and seat valve **140** may be present within the pull tube to allow fluid delivered down the tubing string to be delivered through the jet nozzles **60**. Subsequently, fluid may be circulated to the perforations **36** by flushing the wellbore annulus alone. During this flushing, a sufficient fluid volume may be delivered through the tubing string to maintain the ball within the ball and seat valve **140** within the pull tube **40** in seated position. Should reverse circulation be required, any fluid delivery down the tubing string **10** may be terminated, while delivery of fluid to the wellbore annulus continues. Fluid will circulate through the outer port **95** of the valve housing **100**, and through the inner port **146** of the valve plug. This fluid unseats the ball within the pull tube **40**, and thereby providing a return fluid flowpath to surface through the tubing string. It is noted that such flushing is possible regardless of the position of the valve plug **145** within valve housing **100**, as a fluid pathway from the wellbore to the valve housing is present in any position of the valve plug or sealing assembly. Accordingly, the wellbore annulus may be flushed by forward or reverse circulation even when the sealing element **75** is actuated and valve plug **145** is in the seated position.

A person skilled in the art would appreciate that other configurations of the downhole tool into which the equalization valve is inserted are possible. Moreover, alternative sealing mechanisms are possible so long as the force required to set and unset the sealing element is greater than the force needed to actuate the valve plug from its seated to unseated position.

The equalization valve therefore serves as a multi-function valve, and may be incorporated into various types of downhole assemblies, and manipulated to effect various functions, as required. The equalization valve may be placed within a tubing-deployed assembly and positioned within the assembly to provide selective reverse circulation capability, and to aid in equalizing pressures between wellbore annulus segments, and with the tubing string flowpath to surface.

While the present description focuses primarily on tubing-deployed tool assemblies, a tool assembly with dual-stage equalization passageways may also be deployed on wireline. In a wireline configuration, the valve plug may be actuated mechanically via wireline (for example by hydraulic pressure to set and pulling on the wireline to unset), while the sealing element is actuated by an electrical signal delivered to the tool assembly via wireline.

In the embodiment shown in the drawings, it is advantageous that the pull tube actuates both the equalization plug and the J-mechanism. However, other mechanisms for providing this functionality will be apparent to those skilled in this art field upon reading the present description, and it is understood that such variant should be considered equivalent with and encompassed by the present teaching.

The previous description of the embodiments is provided to enable any person skilled in the art to make or use the downhole tool assembly and the valve. Various modifications to those embodiments will be readily apparent to those skilled in the art, and many modifications and changes to the embodiments set forth above are possible without departing from the scope and spirit of the invention.

The invention claimed is:

1. A tool assembly adapted for connection to a tubing string to be deployed within a cased wellbore, the tool assembly comprising:

a sealing element disposed about a sealing mandrel on the tubing string, the sealing mandrel having a first end and second end, and defining a fluid passageway extending from the first end to the second end, the sealing element being actuable between a set position in which it is engaged against the casing to an unset position in which it is disengaged from the casing; and,

an equalization valve comprising: a valve housing comprising: a first end connectable to the tubing string and a second end connectable to the mandrel disposed on the tubing string, the housing further including a primary fluid passageway defined therethrough; the primary fluid passageway being continuous with a fluid passageway defined in the interior of the mandrel; and an outer port for permitting fluid flow from the interior of the tubing string to the wellbore; and a valve plug slidably disposed within the equalization valve between a seated position and an open position, wherein in the seated position the valve plug is seated against the mandrel to an open position wherein the valve plug is not seated against the mandrel; the valve plug including a conduit which in all valve plug positions is fluidically continuous with the fluid passageway of the mandrel and the length of tubing string above the housing, so as to allow continuous fluid flow across the sealing element disposed on the mandrel when the valve plug is in the seated position and while the sealing element remains engaged against the wellbore.

2. The tool assembly of claim **1**, the valve plug further comprising an inner port which is fluidically continuous with the tubing string.

3. The tool assembly of claim **1**, wherein the conduit of the valve plug is defined within an insert positionable within the valve plug.

4. The tool assembly of claim **1**, wherein the valve plug includes a valve stem for sealingly engaging a valve seat in the mandrel when the valve plug is in the seated position.

5. The tool assembly as in claim **1**, wherein the conduit is between ⅛ inch and 1 inch in diameter.

6. The tool assembly as in claim **1**, further comprising a filter over the conduit for screening debris from passing through the inner passageway defined in the mandrel.

7. The tool assembly of claim **1**, wherein the movement of the valve plug between the open position and the seated position is mediated by application of mechanical force applied to the tubing string.

8. The tool assembly of claim **7**, wherein the mechanical force to move the valve plug to its seated position is less than the mechanical force required to actuate the sealing element such that the sealing element becomes engaged against the wellbore.

9. The tool assembly as in claim **1**, wherein the valve plug is coupled to a pull tube disposed on the tubing string above the valve housing, the pull tube defining an inner flow path which is continuous with the fluid passageway of the valve housing and with the region of the tubing string above the pull tube.

10. The tool assembly as in claim **9**, wherein the valve plug is engaged with the pull tube such that application of mechanical force applied to the pull tube causes the valve plug to move to the seated position.

11. A tool assembly adapted for connection to a tubing string to be deployed within a cased wellbore, the tool assembly comprising:

a sealing element disposed about a sealing mandrel on the tubing string, the sealing mandrel having a first end and second end, and defining a fluid passageway extending from the first end to the second end, the sealing element being actuable between a set position in which the sealing element is engaged against the casing to an unset position in which the sealing element is disengaged from the casing; and,

an equalization valve comprising: a housing having a fluid passageway which is fluidically continuous with the fluid passageway of the sealing mandrel, an outer port for fluid communication between the interior of the tubing string and the annulus defined between the casing and the tubing string; and a valve plug slideable from a seated position in which the valve plug is in sealing engagement with the sealing mandrel to an open position in which the sealing mandrel is unobstructed by the valve plug, the valve plug further comprising a conduit of smaller inside diameter than that of the fluid passageway of the valve housing, to allow for fluid flow to the fluid passageway of the sealing mandrel when the slideable valve plug is in any position,

wherein actuation of the sealing element from the unset to the set position and the actuation of the valve plug from the unseated to seated position is mediated by application of mechanical force to the tubing string.

12. The tool assembly of claim 11, wherein the mechanical force is applied to a pull tube disposed on the tubing string, the pull tube being coupled to the valve plug, and when the valve plug is in the seated position, the pull tube being coupled to the sealing mandrel.

13. The tool assembly of claim 11, wherein the sealing element is actuated by a J-slot mechanism, the J-slot being defined in the outer diameter of the sealing mandrel.

14. The tool assembly as in claim 11, wherein the valve plug includes a valve stem which is sized for mating engagement with the sealing mandrel.

15. The tool assembly as in claim 11, wherein the conduit is defined within a modular insert positionable within the valve stem.

16. The tool assembly as in claim 15, wherein the modular insert is a jet perforation nozzle.

17. The tool assembly as claim 11, wherein the conduit is between ⅛ inch and 1 inch in diameter.

18. The tool assembly as in claim 11, wherein the valve plug further comprises a filter over the conduit for screening debris from passing to the sealing mandrel.

19. A method of continuously equalizing pressure across a sealing assembly deployed in a cased wellbore, the method comprising:

lowering a tubing string having a sealing assembly and equalization valve to a desired location in a wellbore, the tubing string being in fluid communication with the wellbore by a port defined in the equalization valve, the equalization valve having a primary fluid passageway defined therethrough for permitting fluid communication through the tubing string above and below the sealing assembly, and a secondary equalization passageway for allowing a restricted fluid flow above and below the sealing assembly when the equalization valve is in any position;

blocking fluid communication across the primary fluid passageway of the equalization valve;

compressing a sealing element within the sealing assembly to engage and seal against the casing;

permitting a restricted fluid flow to occur through the secondary equalization passageway while the sealing element remains set against the casing;

performing a downhole operation in the cased wellbore while the sealing element is set against the casing and the restricted fluid flow is occurring;

applying a mechanical force to the tubing string to allow fluid flow through the primary equalization passageway across the sealing assembly; and

equalizing pressure across the sealing element such that the sealing element becomes disengaged from the casing.

20. The method of claim 19, further comprising actuating the sealing assembly by a J-mechanism disposed on the region of the tubing string on which the sealing assembly is disposed.

21. The method of claim 19, further comprising permitting fluid flow in a lateral direction between the interior of the tubing string and the annulus defined by the casing and the exterior of the tubing string above the sealing element, while the restricted fluid flow is occurring.

22. The method of claim 19, wherein the downhole operation is fracturing.

23. The method of claim 22, further comprising delivering a fluid down the tubing string such that a ball within a ball and seat valve on the tubing string above the equalization valve is seated, to prevent fluid flow to the equalization valve.

24. The method of claim 23, further comprising the step of delivering fluid down the annulus.

* * * * *